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Preliminary Design of a Drinking-water Carrier for Water Supply to the Croatian Islands

Abstract

An analysis of drinking water supply to the Croatian islands indicates an unsatisfactory situation with drinking water on inhabited and occasionally inhabited islands, as well as frequent shortages of drinking water. Besides the fact that this constitutes an obstacle to the economic development of the islands, the scarcity of drinking water further complicates the everyday life of islanders, especially during the summer months when scarcities are more frequent. A particular problem has been observed on islands where the drinking water is supplied by drinking-water carriers. There are four such ships in Croatia, with an average age of over sixty years, which often fail to meet the island's drinking water demands on time and in sufficient quantity. For strategic reasons, the renovation and strengthening of the Croatian fleet of drinking-water carriers should be definitely considered in order to ensure a secure long-term supply of drinking water to the islands. In the paper a preliminary design of a drinking-water carrier suitable to supply water to the Croatian islands is presented.

Keywords: Croatian islands, drinking water supply, drinking-water carrier, preliminary design

1. Introduction

According to the Croatian Ministry of the Sea, Transport and Infrastructure [1], as many as 1244 major and minor islands, islets and rocks exist in Croatia. The Croatian archipelago is the second largest archipelago in the Mediterranean part of Europe. According to the geographical division, 78 of them are islands, 525 are islets while 641 are rocks. Of 603 islands and islets, 50 are permanently inhabited which is 8.3%.

One of the main prerequisites for living on the island is drinking water, so the fact that only nine islands have their own water resources eligible for use in water supply does not support this in any way [2]. Therefore, only 18% of the Croatian islands have their own water resources, which means that for the remaining 82%, or 41 of them, it is necessary to organize a good water supply in order to allow life to continue on the islands. In addition, it is necessary to ensure quality water supply for the occasionally inhabited islands, which play a very important role in Croatian tourism. These islands

generally receive water from the mainland. Some islands are connected with land by pipelines, while in other islands drinking water is provided in three ways: by desalination of seawater (Susak, Mljet), by collecting rainwater, and if any of this is not possible, water is brought to the islands by drinking-water carriers.

The lack of drinking water on the islands is one of the main causes of the increasing displacement of the island population. Water is needed for basic life functions but also for use in agriculture and economy. The young people, who are mainly both the driving force and the workforce of the island, are emigrating, and an older population remains on the islands. The result is a deterioration of the demographic balance and the decline and suppression of the economy. Life on the island is very restrictive for the development of any more serious business plan, and in any way insufficient water supply does not support it.

The need for additional amounts of water is increasing every year on the islands, and the main reason is higher consumption of water due to the arrival of tourists. Today, marinas are also large consumers of drinking water. The lack of water on the island increases the already present high risk of fire during the summer months.

In some studies [2], the water supply status of the island was addressed and the data are presented in Figure 1.

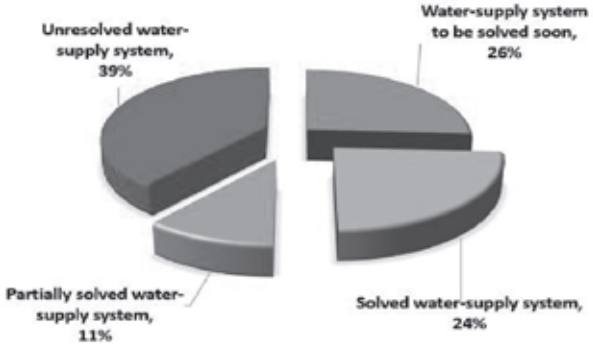

Figure 1: Current situation of water supply in Croatian islands [2]

Some of the largest Croatian islands, such as Cres, Pag, Hvar, Korčula, Mljet, are among the 11% of the islands where the water supply system is partially regulated. These islands have their own water sources through lakes, underground sources, desalination plants, or are connected by pipelines to the coast, but the infrastructure is not yet fully settled. Some of these islands have their own sources of drinking water, but it is not economically feasible to connect every and the least populated settlement on the island to a source of water, so alternative solutions should be devised for such settlments. Islands with large quantities of brackish water could solve their water supply problems by setting up desalination plants and thus providing drinking water throughout the year.

As many as 39% of inhabited islands belong to the group of islands with unresolved water supply issues, which is an extremely large and worrying figure. These are mostly smaller islands, which are quite far from the coast, and are characterized by a small number

of inhabitants living in a small area. These islands include the islands of Unije, Lošinj, Premuda, Silba, Ist, Olib, Molat, Dugi otok, Biševo, etc. The supply of these islands is mainly carried out by drinking-water carriers, and this group of islands has received the most attention in this study. Given the large distance from the shore, it is not profitable to connect these islands by pipelines with water systems on the mainland. In such islands, it is necessary to build or renovate the tanks for receiving water supplied by the drinking-water carriers and to resolve the issue of further transfer of water around the island.

There are four drinking-water carriers in Croatia, with an average age of over sixty years, which often fail to meet the drinking water requirements of the island on time and in sufficient quantity. Therefore, the renewal and reinforcement of the fleet should certainly be of strategic interest to the Republic of Croatia. In this regard, a preliminary project for a drinking-water carrier was initiated, which would enable a more secure supply of drinking water to the Croatian islands.

2. Water Supply Infrastructure of the Croatian Islands

The Croatian islands are supplied with water in three different ways. Some larger islands have their own water sources and tailored infrastructure for transporting water around the island. Islands closer to the mainland receive water from the mainland via underwater pipelines. Outermost islands and those not connected to the mainland by pipelines are supplied with water by drinking-water carriers or in rare cases via desalination plants on the island.

For smaller inhabited islands, which are often quite far from the mainland, their own sources are critical since they often dry up during the summer season when they are most needed. Therefore, existing water supply facilities must be renovated or newly constructed on such islands. This refers to local water reservoirs and water reservoirs on which the central connection is installed. They need to be further extended to provide the necessary water supply infrastructure on the islands.

According to the decision of the Ministry of the Sea, Tourism, Transport and Development [3], smaller, distant and sparsely populated islands not connected to mainland water supply systems would be supplied by drinking-water carriers. Therefore, the aforementioned local water reservoirs are needed, to which the water carrier would connect and pump the brought water into them.

The mentioned problems refer to the islands of the Adriatic Sea, that is, to the Croatian coastal zone, which is divided into five counties, from south to north: Dubrovnik-Neretva, Split-Dalmatia, Šibenik-Knin, Zadar, Primorje-Gorski kotar.

It is necessary to make an analysis of the water supply infrastructure of smaller, distant and populated islands, so it is important to obtain data on the volume of local water reservoirs, average annual drinking water demand of the Adriatic islands and, according to this information, make a preliminary design of a vessel for the transport of drinking water for the supply of water in the Croatian islands.

2.1. Islands of Dubrovnik-Neretva County

The islands of this county generally have a solved water supply issue or are well on their way to fully resolve the issue.

The island of Korčula is connected to the Pelješac peninsula by pipelines and thus has secured water from the mainland.

The island of Lastovo receives water from its own sources, which are often not sufficient during the summer months, so it is necessary to bring the water with a drinking-water carrier or to install another desalinator, which is the intended solution to meet all the needs of the island.

The island of Mljet is connected by underwater pipeline systems to the Regional System Neretva - Pelješac - Korčula - Lastovo. This pipeline was laid in the 1990s, but from a talk with an employee of the Croatian Islands Authority, the pipeline was put into service in summer 2019. So, for about twenty years, the water supply system lay at the bottom of the sea, ready for use and awaiting commissioning. Since Mljet is finally connected to the water supply system with the mainland, there is no longer a need for the arrival of drinking-water carriers, which were until 2019 frequent "visitors" of this island.

2.2. Islands of Split-Dalmatia County

Brač, Hvar and Vis are islands where the water supply network is almost fully functional, but there is room for improvement. The island of Brač is connected by pipelines to Split so that it has secured water supply throughout the year. Hvar is also connected to the water supply network, but the island also has its own water sources. However, due to the large number of people on the island in the middle of the tourist season, sometimes it used to happen that the island run out of water, which in the future could present a major problem for the further development of tourism. Šolta is in the process of solving the water supply issue, and through pipelines it is connected across the island of Brač with the mainland.

On the other hand, the islands of Drvenik Veli and Drvenik Mali face water shortages year after year and this is a big problem for the locals, especially in summer. Therefore, it is necessary to adjust the infrastructure for receiving water from drinking-water carriers. In these islands, the construction of a water supply network is only in the plans, so that they are still compelled to cope in other ways. Two water reservoirs with a total volume of 700 m^3 are mentioned on the island of Drvenik Veli, which would meet the needs of permanent residents, about 180 of them, or about 700 during the summer. Drvenik Mali needs two water reservoirs with a total volume of 200 m^3 in order to provide water for 60 permanent residents and 200 during the summer. Therefore, the two islands together have a water reservoirs volume of 900 m^3.

2.3. Islands of Šibenik-Knin County

The Šibenik archipelago, with its 249 islands, islets and rocks, in addition to the Zadar islands, has the largest number of islands in Croatia. The islands are generally not too big, but they are inhabited and a good water supply plan is required. "Water Supply Plan of the County of Šibenik-Knin" [4] mentions a plan to build the first phase of underwater pipelines to the islands of Kaprije, Žirje and Obonjan. Due to the distance between the islands of Kaprije and Žirje, this part of the project is unlikely to be completed in the near future, and the connection of the island of Obonjan by pipeline to the mainland depends on the development of tourism on the island. In view of the above, the water will continue to be transported by drinking-water carriers to the islands. Also, the islands that are supplied by water carriers include the island of Zlarin, and attention should be paid to it.

The water supply plan of the Šibenik-Knin County [4] contains a tabular overview of the existing water reservoirs from which the data for the above mentioned islands were extracted and shown in Table 1.

Table 1: Overview of existing water reservoirs in Šibenik islands [4]

Island	Water supply area	Capacity, m^3	Number of chambers	Mode of water supply
Zlarin	Zlarin	300	2	Drinking-water carrier
Kaprije	Kaprije	500	2	Drinking-water carrier
Žirje	Žirje	500	2	Drinking-water carrier
Obonjan	Obonjan	1000	2	Drinking-water carrier

2.4. Islands of Zadar County

The Zadar archipelago has about 300 islands and islets and is a famous tourist attraction known all over the world. Most of them are uninhabited, but of course there are larger and more populated ones. It is also required to draw up a water supply plan for these islands, given that the most populated and distant islands have the unresolved water supply issues.

The island of Pag is connected to the coast by a water supply network, as are the islands of Ugljan and Pašman. These islands are near the mainland so they are not in danger of water shortages.

However, this is only the case for these few bigger islands, while in the other islands the situation is different. A common feature of islands with unresolved water supply issues is their size and distance from the mainland. These islands are generally small, with the exception of Dugi Otok, and all are more or less quite distant from the mainland. The plan is to supply these islands with water by drinking-water carriers, so the infrastructure for receiving water should be adapted here as well.

Island of Premuda has one 320 m^3 reservoir, which needs to be renovated and increased the volume to 400 m^3 in order to meet the needs of 56 permanent residents and 200 during the summer season.

On the Island of Molat, water supply is carried out with the help of a local reservoir of 400 m^3 capacity. If the reservoir is not filled with rainwater, a drinking-water carrier is engaged to complement the difference. In addition to the local water reservoir, it is estimated that there are individual cisterns on the island with a total capacity of 2000 m^3. In addition to the rehabilitation of the existing local water reservoir, it is also necessary to build a new water reservoir capable to receive 500 m^3 of water.

Island of Ist is in constant problems with water supply and very often runs out of water. A local water reservoir that receives 300 m^3 of water is damaged and has problems receiving water. The settlement does not have a supply of water during prolonged droughts and this problem needs to be urgently solved.

On the island of Olib only one water reservoir of 250 m^3 is mentioned. Since there are up to 1000 people on the island during the summer, it is clear that the existing water supply is not enough, so the water reservoir needs to be either increased or new built.

Island of Silba has satisfactory water storage capacity, with a total volume of 1050 m^3. Also, a water supply network is already installed on the island so that the island is ready to receive water from drinking-water carriers.

The island of Vrgada also receives its water through water carriers, until the pipeline that connects it to the mainland is built and put into operation. The project is in the final stages of construction and soon the island of Vrgada should receive water from the water supply network of Pakoštane municipality.

Dugi otok is the largest island in the Zadar archipelago and because of its size and distance from the mainland, the water supply plan has not been fully resolved. The southeastern part of the island is supplied both by a local water source and water supply system, but water needs to be desalinated first. In the northwestern part of the island the situation is somewhat different, so the places depend on local water reservoirs. Božava has two water reservoirs with a total volume of 500 m^3, while the water reservoir in Soline has a capacity of 600 m^3.

2.5. Islands of Primorje-Gorski Kotar County

Island of Susak is farthest from the coast in this county and until recently had no water supply system in place. In 2017, the construction of the desalination system was completed and thus the island and its inhabitants received their own drinking water, which is generated by the seawater treatment, i.e. desalination process [5].

The island of Unije has a permanent population of 95, which are suppled by water through house cisterns, supplemented if necessary by a local cistern which is filled with water by a pipeline connected to an island water source.

Larger islands in the area provide water through urban water supply systems or draw water from their own sources. Thus, Vransko Lake in Cres is the main water source for the islands of Cres and Lošinj. The water for the island of Ilovik is delivered through Mali Lošinj by underwater pipeline.

2.6. Water tanks grouped by counties

Table 2 shows the data grouped by the cited counties. From the obtained data it is clear that the water supply infrastructure of the Croatian islands is at a low level and needs to be completely renovated or built. There are many islands where life depends on the water delivered by drinking-water carriers, so there is certainly a logical need for at least one additional water carrier that would significantly assist in supplying the island with water. This need is further reinforced by the fact that the drinking-water carrier fleet in the Republic of Croatia is very old and the question is when some of these ships, on which numerous islanders depend, will deliver their last shipment of water.

Table 2: List of water storage capacities on islands in Croatian counties

County	**Island**	**Volume of water reservoirs, m^3**
Split-Dalmatia	Drvenik Veli	700
	Drvenik Mali	200
Šibenik-Knin	Zlarin	300
	Kaprije	500
	Žirje	500
	Obonjan	1000
Zadar	Premuda	400
	Molat	400 + 500
	Ist	300
	Olib	250
	Silba	1050
	Dugi otok - Božava	500
	Dugi otok - Soline	600
Primorje-Gorski kotar	Susak	2 x 750

2.7. Average annual water needs of Croatian islands

The information about average annual water needs of Croatian islands was obtained from employees of the Croatian Islands Authority. Depending on various factors such as rainfall, occurrence of droughts, number of tourists, etc., the needs of the Croatian islands for the quantities of drinking water vary from year to year. Based on analyzes of data from recent years, these average values presented in Table 3 have been obtained as relevant. The presented data have been obtained in contact with water supply companies, utility companies and drinking-water carrier owners.

Table 3: Average annual needs of Croatian islands for water

Island/archipelago	Annual needs, m^3
Zadars archipelago	30000
Dugi otok	15000
Šibenik archipelago	20000
Drvenik Veli and Drvenik Mali	12000
Mali Lošinj	3000

3. Drinking-Water Carriers in Croatia

There are currently four drinking-water carriers in operation in Croatia. The PT-71 drinking-water carrier is under the jurisdiction of the Croatian Navy [7], while the other three are privately owned. Table 4 provides basic parameters on existing drinking-water carriers.

Table 4 shows that they are a fairly old fleet of ships, three of which are over 60 years old, and an average age is incredible 60 years. With the already existing problems of supplying Croatian islands with drinking water, this information in no way support the solution of this big, to the general public mostly not known problem, on which the survival of people on the inhabited islands literally depends.

A major problem in the supply of drinking water to the islands is also the tenders for the supply of water, which are usually announced too late. The tenders are very illogical in themselves and limit both the clients (locals) and the suppliers of drinking water (water carrier owners). Because of all these mismatches, it is often the case that, during the greatest drinking water supply needs, only one drinking-water carrier is in service and the other three stand unemployed. Although they want to help the islanders, water carrier owners are restricted by contract to certain areas beyond which they may not operate [6]. These tenders are unavoidable for supplying drinking water to the islands, but in principle are unnecessary and create a mess. The main requirement of each tender is the price of water transportation services, so the cheapest water carrier gets the job by this criterion. The consequence is that a single water carrier cannot cover all needs and without delays deliver water to clients.

When applying to a tender, “Bočac” which is the smallest of the three mentioned private owned drinking-water carriers usually gets the job. In this way, other water carriers fall out of the job because as a rule they offer a higher price. The biggest problem here is not paying attention to the wider picture, because for example “Captain Mrs” is twice the size than “Bočac”, so it takes twice less voyage to transport the same amount of water. So the cheaper bidder in the end turns out to be more expensive. Also, only the price is considered as the main criterion when announcing the tender, and a very important factor - the home port - is ignored. For example, “Bočac” sails from Lošinj, which is about 90 nautical miles far from Šibenik. Her cruising speed is about five knots, so with favorable weather conditions it takes about 18 hours to sail in one direction. In this way, the Šibenik islands are dependent on only one water carrier, the smallest and slowest of the three available, resulting in a delay and shortage of water.

Table 4: Basic parameters of drinking-water carriers

Drinking-water carrier	“Kapetan Mrs”	“Bočac”	“Zrmanja”	“PT-71”
Built year	1953	1955	1967	1956
Length overall, m	44.25	33.59	55.6	43.75
Length between perpendiculars, m	40.9	32.2	50.0	-
Breadth, m	7.9	6.7	9.4	8.2
Depth, m	4.17	2.8	4.12	-
Draft, m	3.510	2.372	3.775	3.1 (bow) 3.5 (stern)
Gross tonnage	346	149	424	-
Speed, knot	8.5	5.5	10,0	10.0
Capacity of water tanks, m^3	480	232	950	350
Engine power, kW	221	2x174	808	684
Range, nautical mile	-	-	-	4660

It can also be pointed out that year after year, the company “Hrvatske vode” which manages the waters in Croatia, “benevolently predict a water supply standstill between July 15 and August 15” [6], so the lack of water and the reductions to which the islands are forced seem completely normal and inevitable.

There are various, simple solutions to these problems and one can be to connect the three water carriers into an organized system. In this way, water carriers could by agreement assist any island or area affected by water shortages. There is more than enough job each year for all water carriers, so restricting them to individual areas is pointless.

4. Basic Parameters of the New Drinking-Water Carrier

In the process of designing a ship, a graphical representation in the form of a "design spiral" is commonly used, in which nodes around the spiral represent items that are of importance to the ship being designed, [8]. The design process begins with mission requirements, followed by the development of a concept and preliminary design. The process continues in a circular moving over the nodes in a design spiral, during which the details of the project are refined. The basis of the process is to make enough circles, in a predetermined order, and carry out all calculations necessary to refine the project that will eventually serve as a basis for repetition in the next circle. After passing through several circles over nodes, an increasing level of the project details is obtained compared to the previous circles. During the preliminary design of the drinking-water carrier, two circles were made, and the following features of the ship were taken as nodes in the design spiral:

- Hull form,
- Hydrostatics and freeboard,
- Arrangements,
- Structure,
- Resistance and propulsion,
- Light ship weight estimation,
- Capacities and intact stability.

When designing a drinking-water carrier, the basic requirement is her water capacity. Considering that the water carrier is intended for the transport of drinking water to Croatian islands, the basic criterion was the capacity of water reservoirs on individual islands which are shown in Table 2. According to these data, it was estimated that a satisfactory capacity of the water carrier would be about 900 m^3. With this capacity, a water carrier in one voyage can supply one larger island, or two smaller ones, depending on the infrastructures and capacities to store water on the islands.

After two circles over the design spiral, the basic parameters of the drinking-water carrier shown in Table 5 were obtained. Due to the sea depth limitations of individual ports on the islands, the draft had to be kept at some reasonable value.

Table 5: Basic parameters of a drinking-water carrier

Length overall, m	42,0
Length between perpendiculars, m	38,5
Breadth, m	10,0
Depth, m	4,25
Draft, m	3,71
Capacity of water tanks, m^3	917
Gross tonnage	407,8
Engine power, kW	634

The three-dimensional computer model of the water carrier hull is shown in Figure 2.

Figure 2: The 3D model of drinking-water carrier hull

The performance prediction is shown in Figure 3. The estimated speed is 9.1 knots in sea trial conditions at 90% of the maximum continuous power and draft of 3.71 m. The range was estimated as 1354 nautical miles for a 9 knots cruising speed with a total fuel supply of 21.5 t.

Figure 4 shows the general arrangement plan of the drinking-water carrier.

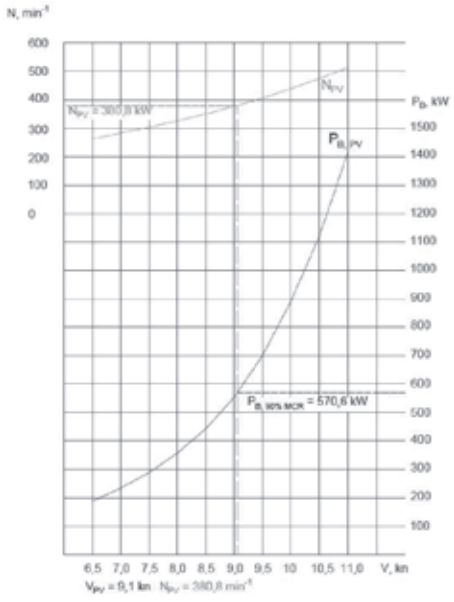

Figure 3: Performance prediction

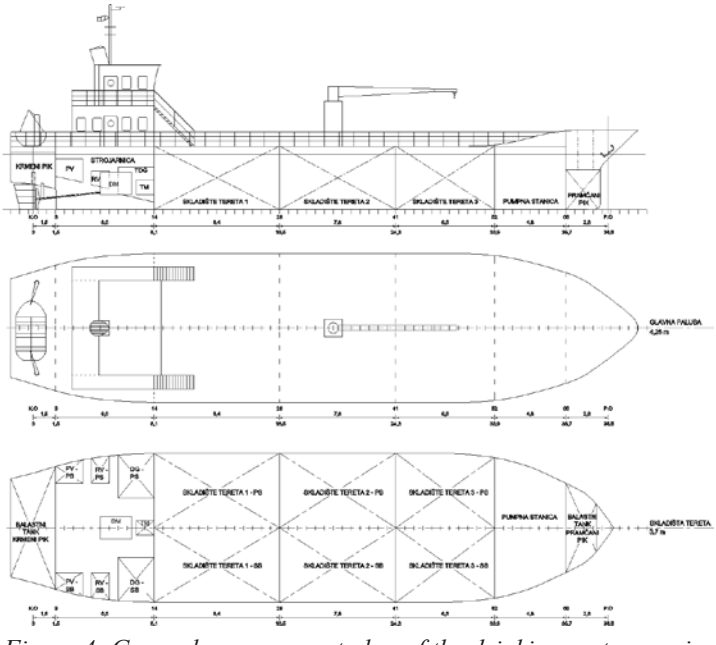

Figure 4: General arrangement plan of the drinking-water carrier

5. Conclusion

Analysis of the supply of drinking water to the Croatian islands indicates an unsatisfactory situation in inhabited and occasionally inhabited islands with frequent shortages of drinking water, especially during the summer months. A particular problem has been observed on islands which are supplied with drinking water by water carriers. There are four such ships in Croatia, with an average age of over sixty years, which often fail to meet the island's drinking water requirements on time and in sufficient quantity. Therefore, the renewal and enhancement of the fleet should certainly be of strategic interest to the Republic of Croatia.

In the paper a preliminary design of a drinking-water carrier that would enable a more secure supply of drinking water to the Croatian islands is presented. The development of the design was somewhat difficult by the scarce data available on the water supply of the Croatian islands according to which the mission requirements for a drinking-water carrier could be defined. Such water carriers are very specific in themselves and they only sail in countries with indented coastline and islands that need to be supplied with water. Because of this, it was very difficult to come up with specific information on similar water carriers that would be used as guidance for the preliminary design of this specific water carrier.

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